Summer 2013

Evidence for a regulatory linkage between leaf water potential and mesophyll conductance

Rafael Contreras Rangel

Evidence for a regulatory linkage between leaf water potential and mesophyll conductance

Rafael Contreras Rangel '14 and Christopher P. Bickford
Kenyon College Department of Biology, Summer 2013

Abstract

The transfer conductance of CO_2 from intercellular airspaces to chloroplast stroma, mesophyll conductance (g_m), is an important but poorly understood process that is widely thought to be highly responsive to changes in soil water content. In this study we examined the relationship between g_m, leaf water status and soil drought. We determined g_m by measuring chlorophyll fluorescence in conjunction with leaf gas exchange in well-watered and water-stressed castor bean (*Ricinus communis*) and tomato (*Solanum lycopersicum*) plants. Leaf water status was determined by measuring lamina water potential with leaf psychrometers. Both the control and water-stressed groups in castor bean and tomato had similar g_m values, with the castor bean showing rates of 0.27 ± 0.02 µmol m^{-2} s^{-1} (well-watered) and 0.32 ± 0.08 µmol m^{-2} s^{-1} (water-stressed; P = 0.57) and tomato exhibiting rates of 0.24 ± 0.02 µmol m^{-2} s^{-1} and 0.22 ± 0.02 µmol m^{-2} s^{-1} respectively (P = 0.56). Likewise, lamina water potential was also similar, with the castor beans having -0.40 ± 0.07 MPa (well-watered) and -0.59 ± 0.12 MPa (water stressed; P = 0.23) and the tomatoes having -0.41 ± 0.07 MPa and -0.53 ± 0.08 MPa (P = 0.29), despite imposing severe soil drought (mean volumetric water content = 11.8%). Overall, the similarity in g_m and water potential observed in well-watered and water-stressed plants indicates a need of further studies to examine the mechanism underlying this response, particularly the role of lamina water potential in regulating g_m.

Introduction

Definitions
- Mesophyll conductance: the transfer conductance of CO_2 from intercellular spaces to chloroplast stroma.
- Chlorophyll fluorescence: Light that has being reemitted after being absorbed by a chlorophyll molecule in the leaf of a plant.
- Water potential: potential energy of water per unit volume relative to pure water.

Increase in Droughts:
- Global warming has been increasing the temperature of the Earth over the past few decades (1).
- Many problems come from increasing global temperatures, including severe weather events, an increase in ocean levels due to the melting of the polar ice sheets, and drought.
- Drought was one of the main problems that the nation had to face this past year, with some parts of the nation experiencing record setting droughts (2).

Negative Effects of Droughts
- Plants experience lower carbon uptake as well as lower photosynthesis rates, ultimately reducing crop yields (3, 4).
- Due to our dependence on agriculture, it is important to understand the ways in which plants combat soil water deprivation caused by drought.

Goal:
- Although it is widely accepted that all plants exhibit lower mesophyll conductance during drought (5), most studies use xylem water potential as an indicator of water stress and ignore lamina water potential.
- In this study, we tested the interactive effects of water stress on mesophyll conductance and lamina water potential in *Ricinus communis* and *Solanum lycopersicum.*

Results

Mesophyll conductance did not vary when *R. communis* and *S. lycopersicum* were water stressed.

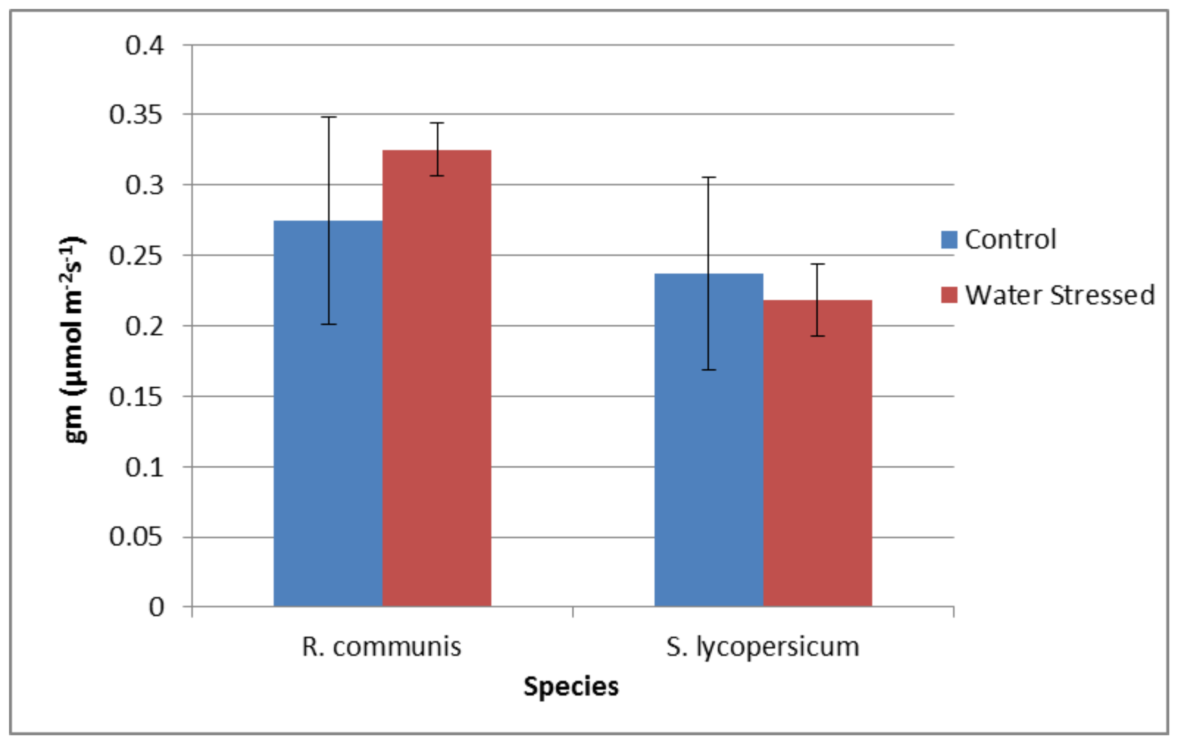

Figure 1: The effect of water stress in the mesophyll conductance of *Ricinus communis* and *Solanum lycopersicum*. Water stressed plants were measured when their volumetric water content (VWC) was between 10-20%, while the control plants were held between 45 - 60%. There was no difference in mesophyll conductance (gm) between control and water-stressed *R. communis* plants, (Two-sample t-test, t = -0.63, p=0.57, d.f. = 3) or *S. lycopersicum* plants (Two-sample t-test, t = -0.61, df= 7, p=0.56). Error bars = 1 SEM

Large differences in volumetric water content were observed between the control and water stressed plants.

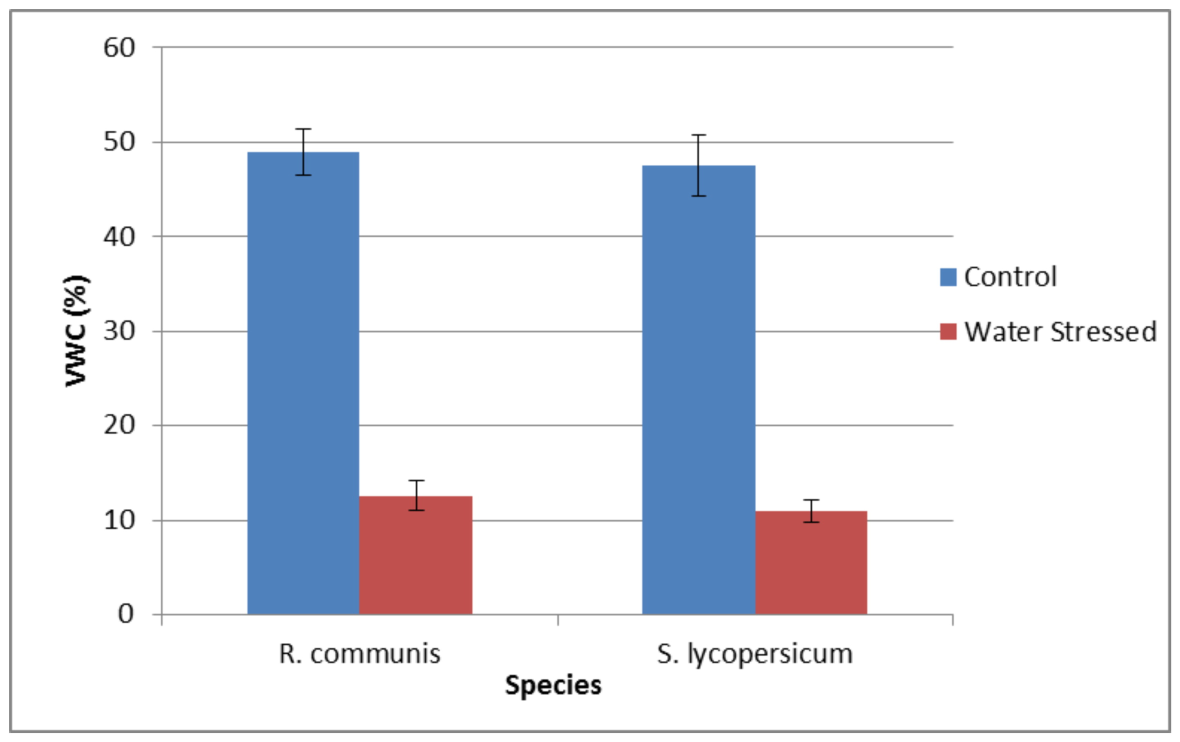

Figure 3: The difference in soil volumetric water content (VWC) between well-watered (control) and water stressed *Ricinus communis* and *Solanum lycopersicum.* The VWC was measured on the day of measurements. The VWC was much higher in the control group than the water stressed group for *R. communis* (Error bars = SEM, Two-sample t, t= 12.71, df= 6, p=0.00) as well as in *S. lycopersicum* (Error bars = SEM, Two-sample t, t= 10.76, df= 5, p=0.00).

There was no significant difference in lamina water potential between control and water stressed plants.

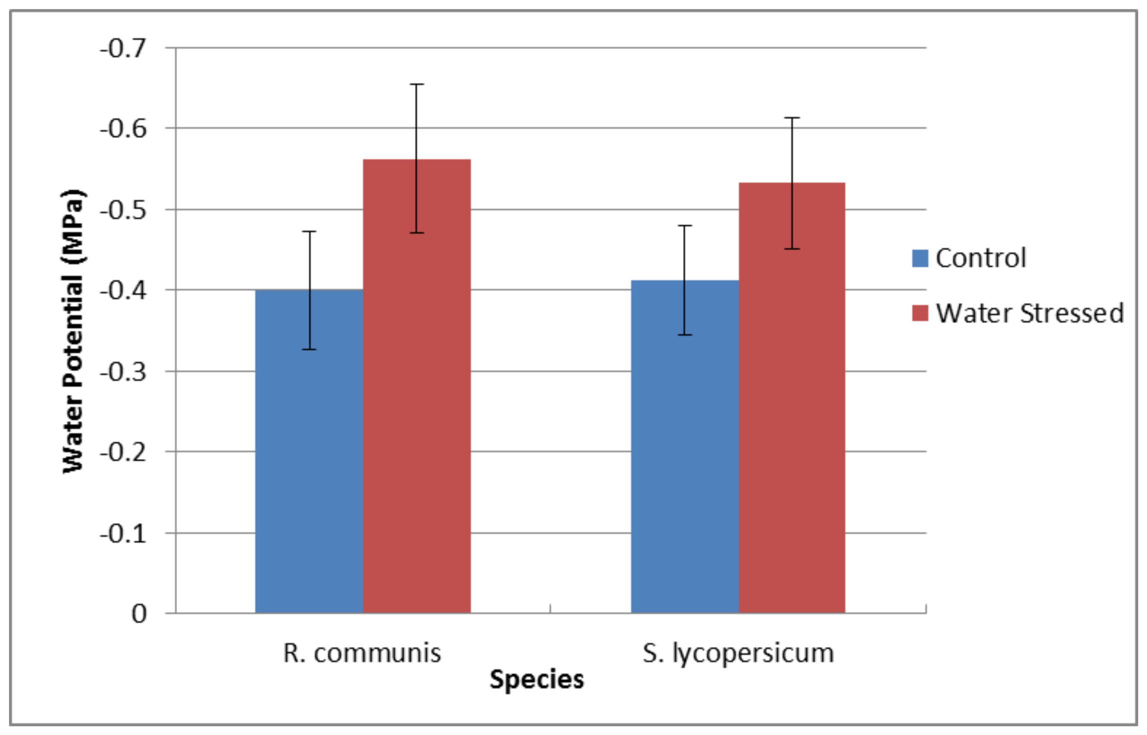

Figure 2: The effect of water stress on the water potential of *Ricinus communis* and *Solanum lycopersicum*. Water stressed plants were measured when their volumetric water content (VWC) was between 10-20%, while the control plants were held between 45 - 60%. There was no significant difference between the control group and the water stressed in *R. communis* (Error bars = SEM, Two-sample t, t = 1.38, df= 7, p=0.21) as well as in *S. lycopersicum* (Error bars = SEM, Two-sample t, t = 1.14, df= 7, p=0.29).

Methods

Tomato (*Solanum lycopersicum*; n = 10) and castor bean (*Ricinus communis*; n = 10) plants were grown in 3.8 L and 5 L pots, respectively, in the Kenyon Greenhouse between May 22 – July 18 2013. Plants were well-watered and fertilized until the onset of experimental conditions. Tomato and castor plants were randomly assigned to experimental (drought) and control (well-watered) conditions. Droughted plants were water stressed to the desired level, and only a minimal amount of water was given to them in order to maintain that level. Five plants of each species were water stressed (10 – 20 % volumetric water content, VWC), while the rest were kept as control (40 – 60 % VWC). The VWC was measured everyday on each plant using a Fieldscout TDR 100 soil moisture meter. All measurements were conducted between 0800 – 1600 on consecutive days.

We measured lamina water potential using a leaf psychrometer (Wescor PSYPRO) and automated datalogging system. Psychrometers were attached to leaves and allowed to equilibrate for ≥ 1 h prior to measurements. Leaf gas exchange and chlorophyll fluorescence were determined using the multi-phase flash routine in a portable photosynthesis system (Li-COR 6400). Leaf gas exchange and chlorophyll fluorescence data were used to estimate mesophyll conductance following Warren (2006) (6):

$$gi = A/Ci - \Gamma*(Ja+8(A+Rd))/Ja-4(A+Rd)$$

Where A is photosynthesis, Ja is electron transport rate, and Rd is dark respiration. The value for Γ* were acquired from Bernacchi et al., (2001) (7).

Conclusions

Findings:
- There was no significant difference in mesophyll conductance or lamina water potential between the control and water stressed groups in both plants studied.
- Both plants studied displayed isohydric characteristics by keeping their water potential constant during severe water stress.

Implications:.
- There could be a regulatory mechanism between lamina water potential and mesophyll conductance.
- Due to the isohydric tendencies in both plants, further studies need to be done in plants that do not keep their water potential constant during drought.

Future Studies:
- Anisohydric plants, which exhibit lower leaf water potential throughout the day as water availability decreases, should be tested using this experimental protocol.

Acknowledgements

I would like to thank my mentor Dr. Chris Bickford for his help and guidance throughout the course of this project. I would also like to thank Molly Goolman as well as Kelsey Dillon for their continuous support in the lab. This project was funded by the Kenyon College Summer Science Scholars Program.

References

1. Cox, Peter M., Betts, R. A., Jones, C. D., Spall, S. A., & Totterdell, I. J. (2000) "Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model." *Nature* 408.6809: 184-187.
2. "State of the ClimateDroughtAnnual 2012." Ncdc.noaa.gov. National Oceanic and Atmospheric Administration, n.d. Web. 29 Jan. 2013
3. Flexas, J., Ribas-Carbó, M., Bota, J., Galmés, J., Henkle, M., Martínez-Cañellas, S., & Medrano, H. (2006) "Decreased Rubisco activity during water stress is not induced by decreased relative water content but related to conditions of low stomatal conductance and chloroplast CO2 concentration." *New Phytologist* 172.1: 73-82.
4. YinPeng, Li., Wei, Y., Meng, W., & XiaoDong, Y. (2009) "Climate change and drought: a risk assessment of crop-yield impacts." *Climate Research* 39.1: 31-46.
5. Flexas, J., Ribas-Carbó, Diaz-Espejo, J., Galmés, J., Medrano, H. (2007) "Mesophyll conductance to CO2: current knowledge and future prospects." *Plant, Cell & Environment* 31.5: 602-621.
6. Warren, Charles. (2006) "Estimating the internal conductance to CO2 movement." *Functional Plant Biology* 33.5: 431-442.
7. Bernacchi! C.J., Singsaas E.L., Pimentel C., Portis A.R. & Long S.P. (2001) Improved Temperature response functions for models of Rubisco-limited photosynthesis." *Plant Cell and Environment* 24: 253-259.